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On the Analysis of Soils, as connected with their Improvement. *By* HUMPHREY DAVY *Esq. F. R. S.*

From the Communications of the Board of Trade.

Concluded from page 269.

XIII. MODE OF DETECTING SULPHATE OF LIME (GYPSUM) AND PHOSPHATE OF LIME, IN SOILS.

Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance four hundred grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

It would not fall within the limits assigned to this paper to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Manganese is now and then found in them, and compounds of barytic earth; but these bodies appear

to bear little relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

XIV. Statement of Results and Products.

When the examination of a soil is completed, the products should be classed, and their quantities added together, and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process XIII. a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the exepriments by which they were obtained.

Thus 400 grains of a good silicious sandy soil may be supposed to contain.

	Grains.
Of water of absorption - - -	18
Of loose stones and gravel principally silicious	42
Of undecompounded vegetable fibres -	10
Of fine silicous sand - - -	200
Of minutely divided matter separated by filtration, and consisting of	270
Carbonate of lime - - 25	
Carbonate of Magnesia - - 4	
Matter destructible by heat, principally vegetable 10	
Silex - - - - 40	
Alumine - - - 32	
Oxyde of iron - - - 4	
Soluble matter, principally sulphate of potash and vegetable extract - 5	
Gypsum - - - 3	
Phosphate of lime - - - 2	125
Amount of all the products	395
Loss - - - -	5

in this instance the loss is supposed small; but in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the processes.

XV. This general Method of Analysis may in many Cases be much simplified.

When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chymical qualities of soils, he will seldom find it necessary to perfom, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid IX. may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air X.; and, in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid XI.

In the first trials that are made by persons unacquainted with chymistry, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of mistakes. The correct analyst ought to be well grounded in chymical general information; but perhaps there is no better mode of gaining it than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books, the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

XVI. On the Improvement of Soils, as connected with the Principle of their Composition.

In cases when a barren soil is examined with a view to its improvement, it ought in all cases if possible, to be compared with an extremely fertile soil in the same neighborhood, and in a similar situation; the difference given by their analyses would indicate the methods of cultivation; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand, in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marle, or chalk to lands, there are no particular chymical principles to be observed; but when quick lime is used, great care must be taken that it is not obtained from the magnesian limestone; for in this case, as has been shewn by Mr. Tennant, it is exceedingly injurious to land§. The magnesian limestone may be distinguished from the common limestone by its greater hardness, and by the length of time that it requires for its solution in acids, and it may be analysed by the process for carbonate of lime and magnesia IX

When the analytical comparison indicates an excess of vegetable matter, as the cause of sterility, it may be destroyed by much pulverization and exposure to air, by paring and burning, or the agency of lately made quick-lime. And the defect of animal and vegetable matter must be supplied by animal or vegetable manure.

XVII. Sterile Soils in different Climates and Situations must differ in Composition.

The general indications of fertility and barrenness, as found by chymical experiments, must necessarily differ

§ Philosophical Transactions for 1799. p. 365. This limestone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

in different climates, and under different circumstances. The power of soils to absorb moisture, a principal essential to their productiveness, ought to be much greater in warm and dry countries than in cold and moist ones; and the quantity of fine aluminous earth they contain larger. Soils likewise that are situated on declivities ought to be more absorbent than those in the same climate on plains or in vallies*. The productiveness of soils must likewise be influenced by the nature of the subsoil, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to, in considering their chymical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may occasionally be prevented from being barren in a moist climate, by the influence of a substratum of sand or gravel.

XVIII. Of the chymical Composition of fertile Corn Soils in this Climate.

Those soils that are most productive of corn contain always certain proportions of aluminous and calcareous earth in a finely divided state, and a certain quantity of vegetable or animal matter.

The quantity of calcareous earth is however very various, and in some cases exceedingly small. A very fertile corn soil from Ormiston in East Lothian afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty five parts of silicious sand, the finely-divided clay amounted to forty-five parts. It lost nine in decomposed animal and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate; for this substance is found in wheat, oats and barley, and may be a part of their food.

* Kirwan, Trans. Irish Academy, vol. V. p. 173.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, I found to consist of one ninth of sand chiefly silicious, and 8-9ths of calcareous marle tinged with iron; and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere§.

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three eighths of clay, two eighths of river sand, and three eighths of the parings of limestone, was very proper for wheat.

XIX. Of the Composition of Soils proper for bulbous Roots and for Trees.

In general, bulbous roots require a soil much more sandy and less absorbent than the grasses. A very good potatoe soil, from Varfel, in Cornwall, afforded me seven eighths of silicious sand; and its absorbent power was so small, that one hundred parts lost only two by drying at 400 Fahrenheit.

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils which are moderately dry, and which do not contain a very great excess of vegetable matter.

I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter. And one hundred parts of the entire soil, submitted to analysis, produced

§ This soil was sent to me by T. Poole, Esquire, of Nether Stowey. It is near the opening of the river Parret into the British Channel but I am told, is never overflowed.

Water	3 Parts
Silex	54
Alumine	28
Carbonate of lime	3
Oxyd of iron	5
Decomposing vegetable matter	4
Loss	3

XX. ADVANTAGES OF IMPROVEMENTS MADE BY CHANGING THE COMPOSITION OF THE EARTHY PARTS OF SOILS.

From the great difference of the causes that influence the productiveness of lands, it is obvious that in the present state of science, no present system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure, a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops; but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expense.

We understand, that a vein of Coal, fine and fertile, has been discovered in Chesterfield, about 3 miles from the banks of the Appamattox, and about twenty above Petersburg. Report says that it was principally traced by the means of the compass from the course of the rich veins on the James River. It will undoubtedly prove, in various lights, a considerable acquisition to the town of Petersburg. May not the same veins extend northwardly to the other watering courses.

Richmond Enquirer.

The editor is happy in the opportunity of presenting to the public "The Lucubrations of *Sylvanus* on soils." They are written by a farmer of considerable acquirements and observation, who resides in one of the lower Counties of Maryland—It is hoped that his laudable example will have many followers.

LUCUBRATION ON SOILS. No. 1.....

The extent of the surface of a continent is so vast the regions it embraces are so numerous, and the kinds of soil in each region are so many, and the resources of individuals are generally so few, that most men are deterred by the magnitude of the task from ever giving a latitude to their reflections on Soils. When they observe the great apparent variety of Soil immediately in their vicinity, or on a single farm, it appears a vain and fruitless task, to attempt to examine the various qualities that are to be found in a great division of the globe. Yet with the very limited knowledge of the subject already acquired, a classification into a few grand divisions, has already been attempted; nor is the task so difficult as at first it would seem. The outlines of the great divisions of soil, are drawn by the hand of nature, in a strong, bold, and conspicuous manner, and may, at any time, be observed by the naturalist, and farmer, sufficiently skilled, and ardent in the pursuit of knowledge, to undertake the necessary fatigue. The attempts (for such they must properly be called,) that have been already made, however imperfect, have greatly contributed to throw light upon the subject, and to conduct the enterprizing mind to further knowledge. With the same good intent, I mean to methodize and state what little I have read upon soils in general, in my hours of study when my plantation work was done, or have learnt by observation in riding through the country—I feel no fear of being deemed presumptuous in expressing my thoughts upon this subject, whatever may be its magnitude, and however few and inconsiderable my observations may be, provided I can throw the smallest ray of light upon a subject, so very useful to all men.

The varieties of soil* in every great division, that could be made, of a portion of the globe, is no doubt considerable; yet every investigating and reflecting mind will perceive, that there must be considerable degrees of affinity in soils, whose foundation is granite, calcareous stone, sand-stone, or that are bedded in schistous rock; so likewise in regions that are alluvial, and in those that are exposed to a marine atmosphere, and those that are exposed to exhalations of a different kind.

The kind of surface which any kind of soil possesses must also give it a peculiar character, visible, and easily understood without the assistance of analysis, or a minute examination. With the assistance of these and such like striking traits, and distinctive characteristic marks apparent, at first view, to the eye of the most unlettered farmer, an arrangement and classification might be made, that would not be without its uses. The surface of the soil has more to do with the labours of the farmer, and the productions of the earth, than the interior structure. The fertility of soils depends also more upon their surface, than is at first imagined, as I will shew in the sequel.

A classification bottomed upon the subterranean geography of a country, would no doubt be desirable, not only to the artist, mineralogist, and chymist, but would greatly assist the agriculturalist—in as much as it would set bounds, more precise and accurate, to the different regions, and more clearly develope the occult affinities and differences of soil. But this requires resources and

* "Soils as Kirwin observes, consist of different combinations of two or more of the four primitive earths, namely the calcareous (which I sometimes call mild calx) magnesia, argil and the silicious. For a more accurate description of these, I must refer to books of mineralogy, and shall only remark, that by calcareous earths are meant chalk and all stones that burn to lime. They are easily distinguished by their property of effervescing with acids."

labours, too great for private individual enterprize. Therefore, without embarrassing this sketch with vain regrets, at not being able to do more, I will proceed to state what I do know.

As we approach the land from the great watery region, the first kind of land we meet with, are beaches of sand forming islands, and peninsulas, stretching along the main land according to the course of currents, or the beating of the surf, or the form of the main lands: and differs from the most kind of land, in as much as it is formed out of pure sand, pebbles, and undecayed seashell. The next kind is the river formed land, or alluvial region, formed by the sediment of rivers, and composed of clay and sand, intermixed in nearly equal proportions, at least when it is first deposited. Some writers have extended this region to the foot of the mountains; and Evans, the geographer, and Volney, have extended the littorral or beachy region to the cascades or tidewater. There may be some good reasons for thus bounding these regions; but as the rivers I conceive have had the latest agency in the formation of the soil, from the falls or cascades to the mouth of the rivers, it appears to me, that that tract of country contained within a line drawn from the head of tide water to the mouths of the rivers, may more appropriately be called the alluvial region; and the beaches and islands of sand, which stud, point, and fringe the coast, alone I call the *littoral or beachy region.* From tide water to the foot of the mountains, may safely be classed by itself, and termed the *hilly or tideless region.* The mountains and their vallies are properly denominated the *mountainous region,* or parent soil, from which, in all times, new soils are forming. Insufficient and indefinite as these divisions are, they may serve as the beginning of a system of classification, and to establish a few conspicuous land marks, to guide the inquisitive farmer in his researches. After having briefly described a few distinctive features of each of these grand divisions, and given some of the most prominent qualities

of the soil, interspersed with a few explanatory and generalizing ideas, I will proceed to a more minute and specific description of the soils, most commonly found, giving this analysis as taken chiefly from Kirwan and the most approved chymical writers, shewing what constitutes a fertile soil, and in what they differ in each of the above grand divisions, and in what consists the chief food of plants.

First then, let us recapitulate the grand divisions:—They are four in number, viz.

The Beachy or Littoral Region.
The Alluvial Region.
The Hilly or Tideless Region.
The Mountainous Region.

It will at once be seen, that each of these regions is susceptible of almost innumerable divisions and sub-divisions, or genera and species. To attain to a full and perfect knowledge of these, is the grand desideratum of farmers, and I trust that the united labors of a great Agricultural nation, enjoying the blessings of freedom, and abundance, will, by continuing to accumulate atoms, in no distant time, arrive at this Herculanean goal of their enquiries.

Of the properties and distinct qualities of soil to be found in the beachy region. In general it is a very light soil, consisting of sand and a portion of calcareous matter, bedded on rock, generally the primœval rock or granite. Sometimes islands or mounds of sand and pebbles, are thrown up by the force and long continuance of currents alone In general the soil of this region is little fitted to the purposes of Agriculture. Some of the islands along our coast, are, however, from particular local causes, exceptions to this rule.

The alluvial region, according to the definition already given, is the river formed land, and extends to the falls of the rivers. This region, therefore, from its extent, contains many kinds of soil, susceptible of divisions by well marked and distinct boundaries, which may be traced on the surface with sufficient clearness, to give a

just perception of them. Before, however, we proceed to attempt to set bounds to the principal divisions of this region, it will be satisfactory to give some idea of its formation, and this I cannot do better than by commencing with the description given by Mr. Volney, in speaking of what *he* calls the alluvial or river formed soil of the United States, in the following words:—

"The remaining region is the country which undulates beyond the ridge of Talc, to the foot of the Sand Stone, or granitic mountains. This limit is traced with most difficulty in Western Georgia, where the vein of Talc does not shew itself. This surface is distinguished by its risings, sometimes in long waves, and sometimes into round and insulated eminences; by the variety of its earths and stones, sometimes confused, and sometimes arranged with regularity, and which appear and disappear many times successively, from the mountains to the maritime plain; always bearing the appearance of having been brought gradually down by the rains and rivers, from the heights, and such in truth, is the origin of all this country. When we calculate the volume, the rapidity, and the number of these streams; of the Delaware, Schuylkill, Susquehannah, Potomak, Rappahannock, York and James Rivers, &c—when we observe that long before their mixture with the ocean, they spread themselves to a breadth of from half a mile to three miles, over a bottom from twenty to sixty feet deep; that in their annual floods, they rise sometimes to a height of twenty feet above their ordinary level, we shall easily perceive what immense portions of earthy matter must be carried about; especially as in former ages the mountains must have had a greater elevation and of course given greater swiftness and force to the torrents; that the forest trees torn up and carried off by thousands, added to their destructive course; that the ice accumulated by six months of winter, forms vast mounds, such as took place in 1784, in the Susquehannah, at McCall's ferry, near Columbia, where a barrier of this kind more than thirty feet high, was formed by

the *breaking up*, and laid the whole valleys under water. At these periods when the ocean bathed the foot of the mountains, of which there are every where manifest traces, the higher mountains, as yet undiminished by the loss of those particles of which time and the torrents have since despoiled them, augmented the motion and force of the descending waters, by the height and abruptness of their points. Their summits being colder, were covered with deeper snows for a longer time, and when the heats of summer, shorter no doubt but not less intense than at present, dissolved these snows, the torrents, thus formed involved a greater quantity of earth, hollowed out deeper channels, and bore away trees with their roots, and large masses of soil connected with their fibres, all which they deposited in the lowest shelves of the mountains. In following years new wrecks accumulate and cloy the ancient channels: the torrents impeded thus by mounds of their own creating, have their volume and impetuosity augmented, till they find their way through the weakest part, and carry the softer matters onward by new channels, while the more ponderous fragments remain behind By a process of this kind continuing incessantly for ages, the beds of ancient torrents enlarge gradually into vallies, and what were once sharp edges or hard bottoms of the streams, become slopes and plains. The waters descending from level to level, and leaving at each resting place their grosser matters, gradually deposit the lighter and more soluble; thus circumscribing the ocean by continual accessions of sand, mud and pebbles, all of which are arrested and bound together by the trunks and branches of trees. The Mississippi offers a luminous example of all these operations. It has been computed by Liancourt that between 1720 and 1800 a period of eighty years, this river has advanced its banks fifteen miles into the sea. Thus under the eyes of three generations, it has raised a new country from the sea which daily encreases, and where beds of coal are slowly forming, and accumulating for the use of future ages. So rapidly does this deposition

take place, that at New-Orleans, three hundred miles above the actual mouth of the river a canal lately dug by the Baron de Carondelet, between Lake Pont Chartrain and the Mississippi, has brought to light a substratum of black earth, mixed with remains of trees, which have neither had time to be decomposed nor converted into coal. The two banks of the river are entirely composed of trunks of trees cemented together by mud, for a length of upwards of three hundred leagues to the height of twelve or sixteen feet. Hence it is, that the vernal inundation which swells the river thirty feet above its ordinary level, and overflows the adjacent country, which is lower than the bank, is hindered from entirely returning, and stagnates into immense marshes. These swamps are at present a bar to culture and population, though hereafter they may supply the means of inexhaustible fertility."

To these observations of Mr. Volney, the correctness of which no one who will take the necessary pains to investigate, can doubt, we shall add a few more to shew the other processes of nature, that contribute to the formation of this region. The clay, stone, sand, ligneous and vegetable substances, that are thus brought down from the heights by the waters, deposit themselves along the bottoms and margins of the rivers, forming shelves, plains and banks. On these banks there is an annual growth of aquatic vegetables which periodically decay, and thereby add to the surface; in addition to which, there is an annual deposit of shells and other marine substances, the increase of which is very great and beyond computation. Shell fish, at least the most common kinds, require little more than a year to get their full growth, and very soon decay. These form strata, which are again covered by the sediment of the river, and re-placed by a new growth of shells; thus is the land continually increased by a slow and gradual process. When in the lapse of time these banks immerge from beneath the water and become exposed to the genial rays of the Sun, they are in a short time covered with her-

bage and trees, whose decay serve again to fix the fluid, and to give to this new made land a yearly coat of loam, which increases its fertility and consequent deposits.

Thus the growth and decay of aquatic, vegetable and animal substances, and the fall of leaves and trees, the annual decay of herbage, and we may add the mortality of animals, assist in the formation of the alluvial region.

The extent of this region is great, and the surface various and capable of many and great divisions. The first division that presents itself, and that may be traced by a strong line, is that tract of land which commences at the mouths of all great rivers, and is bounded by a regular mound or ridge, shaping its course in conformity to the course of the rivers, and of the inlets and creeks that make into the rivers. The surface of this land is almost a perfect level, and not raised many feet above the water; on the surface very little stone is to be found. The soil of this division which for sake of distinction, may appropriately be called "The flat stoneless" division, is almost in all its parts an even mixture of sand and clay, interspersed with calcareous substances in a great state of division, together with a considerable proportion of decayed vegetable matter, just as it was deposited by the water, and in the ways already mentioned, without having existed centuries sufficient to become completely amalgamated. This flat stoneless region on the eastern and western shores of Virginia and Maryland, occupies a considerable space at the mouths and along the banks of the principal rivers and creeks, and is nearly all one and the same soil; occasionally interspersed with ridges of sand: a great portion of it is a stiff soil, and from its stiffness it is supposed by superficial observers to be a clay soil, or to have what is called a clay foundation; this is on examination found to be erroneous, though it has a sufficiency of clay for every agricultural purpose, and for making of bricks. It may properly be termed a loam—by loam I mean a soil of clay, sand and decayed vegetable substances, mixed. It was no doubt a very fertile soil until it was impoverished

by bad cultivation. The stiffness of this kind of land is not so much owing to its component parts as to its surface. If it was situated on declivities it would be of a loose and open texture; but situated as it is with a very level surface, it holds water a long time, which causes it to sob, and after to bake and become very adhesive, and this circumstance gives to this whole region the appearance of a stiff clay soil. Wherever this kind of land is well drained by ditches, it grows perceptibly more loose and light, and where there are natural drains formed by the undulation of the land, or where there are knowls or detached risings it is uniformly a light and open soil, because it never bakes, and because its particles of clay, mixing with the water, are lessened and carried off by every rain. The proportion of sand is greater, and always still more increased by bad cultivation. Under good cultivation its increasing lightness or looseness will be properly checked by deep ploughing and by vegetation, and will become advantageous. Under bad cultivation its increasing lightness will yearly add to its poverty. This kind of soil, in the states mentioned, is well adapted to wheat, the lighter parts to rye and Indian corn. The marginal part of this first step in Virginia and Maryland is covered altogether with resinous trees, chiefly the long leafed yellow pine, cedar and gum; a little distance from the margin you find the woods intermixed with oak, chiefly white oak. The proportion of oaks increases until they occupy nearly the whole ground at the foot of the first rising or gravelly ridge, which bounds the flat stoneless region; at least we find it so where the primitive growth has never been cut down. In this region the calcareous substances that are found in any quantity, are generally only in a small state of decay.

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